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Zoogeography in southern Japan as revealed by ground-living arachnids

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Zoogeography in southern Japan as revealed by ground-living arachnids. - In the past, primarily birds and butterflies, but also amphibians, reptiles and mammals, have been used for zoogeographic studies in southern Japan. Meanwhile, taxonomic studies have also been carried out on arthropod groups living in and on the soil. Since it is quite unlikely that these ground-living organisms have crossed the sea, either actively or passively, they are ideal for zoogeographic studies. The present investigations are based on four groups of ground-living arachnids: whipscorpions and spiders (Hexathelidae, Ctenizidae, Mesothelae). A close zoogeographical connection was found between the Yaeyama Islands and nearby Taiwan. The central and northern parts of the Ryukyu Islands are faunistically closest to Kyushu. No distinct border between an Oriental and a Palaearctic fauna can be detected. Instead, only climatic and other ecological factors appear to be responsible for distributional boundaries of various organisms observed in different regions of southern Japan. Similarities to the fauna of continental China can be explained by land connections between the Ryukyus and the continent during the Pleistocene.

Key-words: Arachnida - zoogeography - Uropygi - Mesothelae - Hexathelidae - Ctenizidae - Japan - Taiwan.

INTRODUCTION

According to differences in the possibilities of distribution of species concerned, conclusions can be drawn about their origin from geographic refugia during the ice ages. More easily distributing species can expand their ranges more quickly and effectively. With every typhoon, flying species like birds or butterflies are brought north, both welcomed by excited birdwatchers and butterfly collectors, but in general none of these stray species is able to establish permanent footholds farther north. This is certainly due to climatic and maybe also other ecological reasons. There may be no more suitable free ecological niches available.

Several attempts have been made to establish zoogeographic lines in southern Japan, mostly based on the distribution of insects (the Miyake Line south of Kyushu)

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(Ezaki, 1929), on the distribution of amphibians, reptiles and mammals (the Watase- or Aoki Line at the Tokara trench) (Okada & Koba, 1931; Hikida *et al.*, 1992; Hikida & Ota, 1997) or on the distribution of insects and birds (the Hachisuga Line at the Kerama trench) (Paik, 1953). Such efforts date back to Watase (1912), who distinguished three zoogeographic areas in the region: 1) Taiwan (and the Ryukyus), 2) the region of Satsuma extending from Kyushu up to central Honshu, and 3) northern Honshu and Hokkaido.

While previous studies have concentrated on the groups of animals mentioned before, species living in and on the ground are much less likely to migrate or to be dispersed passively. Consequently, they are better suited to mirror the prehistoric biogeographic situation. For this reason, different groups of arachnids, which were revised taxonomically during recent years, were used for the current study.

MATERIAL AND METHODS

Based on taxonomic studies of Uropygi (see Haupt & Song, 1996), Mesothelae (see Haupt, 1983; Song & Haupt, 1984), the hexathelid genus *Macrothele* (see Shimojana & Haupt, 1998) and the ctenizid genus *Latouchia* (see Haupt & Shimojana, 2001), distribution data have been compiled in order to elucidate the zoogeographic situation in southern Japan. Specimens mentioned are partly deposited in the Muséum d'histoire naturelle of Geneva.

RESULTS

The following species* were used for the current study; their distribution as documented by the current knowledge is summarized in fig. 1.

Uropygi: *Typopeltis stimpsoni* (Wood, 1862) (Amamioshima) (Haupt & Song, 1996), *T. stimpsoni* (Amamioshima) (Zoological Museum Moscow, unpubl.), *T. stimpsoni* (Kyushu) (Yoshikura, 1965), *T. stimpsoni* (Izena) (Ikehara & Shimojana, 1975).

Typopeltis crucifer Pocock, 1894 (Okinawa and Iheya) (Ikehara & Shimojana, 1975), *T. crucifer* (Ishigaki and Iriomote) (Haupt & Song, 1996), *T. crucifer* (Taiwan) (Haupt & Song, 1996 and Hungarian National Museum Budapest, unpubl.), *T. crucifer* (Kashoto = Lùdao, Green Island) (Haupt & Song, 1996 and Hungarian National Museum Budapest, unpubl.), *T. crucifer* (Lanyu = Orchid Island) (J. Haupt, unpubl.).

Mesothelae*: Heptathela kimurai kimurai* (Kyushu) (Haupt, 1983), *H. kimurai amamiensis* (Amamioshima) (Haupt, 1983), *H. kimurai yanbaruensis* (Yanbaru, northern Okinawa) (Haupt, 1983), *H. kanenoi* (Tokunoshima) (Ono, 1996), *H. kikuyai, H. nishikawai, H. yaginumai* (all Kyushu), *H. yakushimaensis* (Yakushima) (Ono, 1998).

*Ryuthela** *nishihirai nishihirai* (central and southern Okinawa) (Haupt, 1983), *R. nishihirai ishigakiensis* (Ishigaki and Iriomote) (Haupt, 1983), *R. sasakii* (Kumejima), *R. secundaria* (Kumejima), *R. owadai* (Tokashiki, Kerama), *R. tanikawai* (Iriomote) (Ono, 1997).

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* Taxonomic note: In the current catalogue of spiders (Platnick, 2002) *Ryuthela* is still synonymized with *Heptathela*. On the other hand I do not support the description of new species instead of subspecies from various islands in the region, for this reason names of *Heptathela* and *Ryuthela* have been used as published originally.

FIG. 1

Distribution of some ground-living arachnids in the Ryukyus and their neighbourhood. Bars indicate the distribution borders between the whipscorpions *Typopeltis stimpsoni* (Ts) and *Typopeltis crucifer* (Tc) (Uropygi: Thelyphonida), *Heptathela* (H) and *Ryuthela* (R) (Araneae: Mesothelae) and subspecies of the ctenizids *Latouchia swinhoei* (Ls) and subspecies of *Latouchia formosensis* (Lf). This border line coincides with the northern distribution of the hexathelid *Macrothele gigas* (Mg) which is also found in Taiwan. The position of *Latouchia japonica* (Lj) remains questionable as the male is still unknown. Note that none of the distribution boundaries coincides with zoogeographical lines established previously.

Ctenizidae: *Latouchia formosensis formosensis* (Taiwan) (Haupt & Shimojana, 2001), *L. formosensis hyla* (Kuroshima, Iriomote) (Haupt & Shimojana, 2001), *L. swinhoei swinhoei* (Okinawa) (Haupt & Shimojana, 2001), *L. swinhoei xena* (Amamioshima, Tokunoshima) (Haupt & Shimojana, 2001), *L. swinhoei crypta* (Kyushu) (Haupt & Shimojana, 2001), *L. swinhoei typica* (Honshu) (Haupt & Shimojana, 2001).

Hexathelidae: *Macrothele gigas* (Ishigaki, Iriomote, Taiwan) (Shimojana & Haupt, 1998; Tso, pers. comm.).

DISCUSSION

Populations isolated on different islands certainly make their own progress towards speciation. During recent years several new species, e.g., of Mesothelae, have been described from the Ryukyus (Ono, 1996, 1997), showing that *Heptathela* and *Ryuthela* are also present on additional islands such as Tokara, Kerama or Kumejima, respectively. In fact, the description of new island species or the upgrading of subspecies to species level does not affect our interpretation: In this context it is not important whether an insular population has already obtained independent species status or not, because we have to look at the phylogenetic relationships documented by common derived morphological (synapomorphic) characters. Here, we concentrate on genera as mesothelid spiders are concerned, as this clarifies the situation more distinctly.

The continental Chinese mesothelid species are clearly separated from the Japanese and Ryukyuan ones (Song & Haupt, 1984). Although Ono & Nishikawa (1989) tried to link the Japanese *Heptathela kimurai amamiensis* Haupt, 1983 to the Chinese *H. hangzhouensis* Chen, Zhang et Zhu, 1981, the former is more closely related to neighbours in the north (Kyushu) and in the south (Okinawa: Yanbaru), as it shares synapomorphic characters with them. This evaluation is based on the morphology of the female genital plate with its ventrolateral depressions, and on the different parts of the male palpal organ (Haupt, 1983, Song & Haupt, 1984). Therefore the phylogenetic relationships between mesothelid populations on Kyushu and in the northern Ryukyus, including Northern Okinawa (Yanbaru), have to be considered as being closer within each other than with species on the continent (Haupt, 1990). This fact supports the hypothesis that the connection to the continent broke up earlier than the connection between the northern and central Ryukyu islands and Kyushu, which is in accordance with geological data (Kimura, 1996).

Since mesothelid spiders have not yet been recorded from Taiwan (Chen, 1996), they cannot be used to determine the zoogeographical relationship between the Yaeyama Islands (especially Ishigaki and Iriomote) and Taiwan. For this purpose mygalomorph spiders of the families Ctenizidae and Hexathelidae are suitable (fig. 1). They prove a closer zoogeographical connection between Yaeyama and Taiwan. Such relationship (between Yaeyama and eastern Taiwan) has also been reported for the frog *Rana limnocharis* Wiegmann, 1835 (Toda, 1999). In fact these observations are not surprising, as the Yaeyama islands are located rather close to Taiwan. It is known that populations on islands which are in close proximity are also more closely related to

each other than populations from islands farther apart (Mac Arthur & Wilson, 1963). In this context it is surprising that Kimoto (1982), who worked on Chrysomelid beetles, also included Yaeyama as the southernmost Ryukyus, when he stated a close connection between Ryukyus and Kyushu.

While the trench between Okinawa and Miyako (Hachisuga Line) has often been considered as an important dividing line, our results show that this is obviously not the case as far as the arachnids examined are concerned (fig. 1). *Ryuthela* (Mesothelae) and *Typopeltis crucifer* (Uropygi) are transgressing this line concerning their distribution. The distribution of *Typopeltis stimpsoni* and of *Latouchia swinhoei* clearly points to the fact that also the Watase Line (Tokara trench) as well as the Miyake Line have not played any role in the dispersal of these species.

Paik (1953) tried to establish a special biogeographic delimination linked to the northern distribution of *Heptathela* (Aso Line on Kyushu), but *Latouchia* occurs as far north as Tokyo. As both genera, *Heptathela* and *Latouchia*, share the same lifestyle as trapdoor spiders, this clearly demonstrates the climatic reasons for differences in northern distribution. *Latouchia* may be slightly better adapted to colder climate than *Heptathela*.

Furthermore, the northern and southern distribution boundaries of arachnid species studied do not coincide. The distribution border between *Ryuthela* and *Heptathela* is found in the northern part of Okinawa (Yanbaru) and not between separate islands, although some low-lying parts of Yanbaru were possibly submerged during certain interglacial periods.

Obviously, climatic differences present on the continent are also manifested in the Ryukyu Islands. This is apparently the only possibility to explain the current distribution pattern in various groups of ground-living arachnids. Similarities in the species spectrum between the Ryukyus and the continent can be explained by the pleistocene land connection (Kimura, 1996). Since then the islands were cut off and its fauna undertook a separate development.

CONCLUSION

To summarise, all these data provide evidence for a transient zone and suggest that there is no distinct border line between the Oriental and the Palaearctic fauna in the Ryukyu Islands of southern Japan. Biogeographic lines which were established before and partly mark geological trenches are not supported by the distribution of ground-living arachnids. Their distribution mirrors climatic factors.

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